OUTLINE OF SECTION C. ENVIRONMENTAL ASSESSMENT

C. ENVIRONMENTAL ASSESSMENT

1. Use Characterization

Terbufos is a systemic organophosphate pesticide used for control of soil pests (insects and/or nematodes) on corn (field and sweet corn), grain sorghum, and sugar beets. As a systemic insecticide Terbufos can also be used for control of sucking insects such as greenbug and chinch bug.

A communication from American Cyanamid (10/12/98) describes Terbufos products as follows: "Terbufos was first registered in 1974. The American Cyanamid product, COUNTER, is currently marketed as either a clay-based granule containing 15% active ingredient or a polymer-based granule containing 20% a.i. The insecticide is labeled for use on corn, sugar beets, and grain sorghum. COUNTER applications are restricted to ground equipment and are made at planting (in-furrow or banded), at cultivation, or post-emergent over the crop row. The product is classified as 'restricted use' due to acute oral and dermal toxicity. Currently 75% of COUNTER is sold in the LOCK'n LOAD® closed handling system. The LOCK'n LOAD® returnable container eliminates the bag disposal problem and reduces the possibility of accidental spills."

Corn accounts for about 90% of Terbufos use by pounds. The extensive use on corn is due to a large degree to use for control of corn rootworm, but Terbufos is used for control of a wide spectrum of corn pests, depending to some degree on region.

About 90% of Terbufos (pounds) use on field corn is accounted for by the following states: Colorado, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Nebraska, North Carolina, Ohio, South Dakota, Texas, and Wisconsin. There is significant variation in rainfall and other climatic variables within this region. Some regions of high ground water vulnerability may be affected by Terbufos use on corn. Runoff events causing surface water contamination are expected to be less frequent in the more arid, western parts of the corn growing region.

Grain sorghum cultivation overlaps very broadly with cultivation of corn. However, sorghum is somewhat more tolerant of low moisture. Consequently Terbufos use on sorghum may result in less surface water contamination than Terbufos use on corn. Sorghum production is particularly concentrated in Kansas and the Texas and Oklahoma panhandles. Most of Terbufos use on grain sorghum (by pounds) is accounted for by Kansas and Texas.

Terbufos use on sugar beets is localized in the mountain and northern plains states of the Western U.S. About 95% of Terbufos use (pounds) on sugar beets is accounted for by Idaho, Minnesota, Montana, North Dakota, and Wyoming. Close to half of Terbufos use (pounds) on sugar beets is in Minnesota and North Dakota. This use is probably accounted for largely by use in the Valley of the Red River, along the border of North Dakota and Minnesota. Terbufos is not registered for use in California, a state with significant sugar beet production.

Information on use rates, and estimates of relative importance of different application procedures, are displayed on the page following. The information is primarily from a Fax communication from J. Wrubel (9/16/97). A recent reduction in maximum rates for knifed-in applications to sugar beets and sorghum has been incorporated.

The rates in the table following are in lb/A. Assessment of risk to terrestrial wildlife requires rates in pounds per 1000 feet of row. Such rates are specified separately on the labels (see RQ tables in terrestrial risk assessment).

Application procedures for Terbufos involve varying degrees of soil incorporation. Banded and in-furrow application procedures involve relatively less complete incorporation. In the terrestrial nontarget risk assessment EFED has assumed that 15% of granules are available to wildlife for banded application, versus 1% with other incorporation procedures.

Use information for Terbufos

Crop	Max rate ai/A (typical ai/A)	Application technique	Percent of total use	Notes
Corn (field,sweet,pop)	1.3 lb ai/A (1.1 lb ai/A)	**At planting**: In-furrow or in a 7-inch band lightly incorporated with drag chains or tines. **Post-emergent:** Apply granules in a band over the row early in the growing season (1-6 leaf stage) and lightly incorporate with suitable implements. **At cultivation**: Apply granules to the base (or over the top) of plants and cover with soil using cultivation shovels.	95% of COUNTER on corn is applied at planting and 85% of that use is banded.	•Only one application (either at planting, post emergent, or at cultivation) per season. •A reduced rate (0.75 lb ai/A) can be used on “first year” corn. •Light incorporation places granules no deeper than 1 inch.
Grain sorghum	2 lb ai/A for knifed-in only (0.75 lb ai/A) 2.0 lb ai/A for banded applications (0.75 lb ai/A)	**At bedding**: Knifed in at 1-4" below the seed or 1-4" below the seed and up to 5" to the side. **At planting**: Knifed in 1-4" below the seed or 1-4" below the seed and up to 5" to the side or applied in a 7" band incorporated with drag chains or tines.	Greater than 95% of granules are applied in a band.	•Only one application (either at bedding or at planting) per season. •Light incorporation places granules no deeper than 1".
Sugar beets	2 lb ai/A for knifed in only (1.1 lb ai/A) 2.0 lb ai/A for banded & in furrow (1.1 lb ai/A)	**At planting**: Knifed in 2" to the side and 2-4" below the seed; or 5-7" banded and lightly incorporated; or in-furrow. **Post emergent**: Banded over the row and lightly incorporated with cultivation shovels.	60% of the granules applied at planting are banded and 40% are applied in furrow.	•Only one application (either at planting or post emergent)per season. •Light incorporation places granules no deeper than 1".

2. Environmental Fate

a. Environmental Fate Assessment

The acceptable data and published literature give a consistent understanding of Terbufos dissipation in the environment.

Hydrolysis and biodegradation are the primary dissipation processes for Terbufos in the environment when Terbufos is incorporated into soil. Under conditions favorable to microbial growth, the linear metabolic half-life in aerobic soil is approximately 27 days (5.6 days for non-linear) and in anaerobic soil is 67 days (21 days for non-linear). Under abiotic conditions, the hydrolysis half-life is 12.3-13.7 days in the typical range of environmental pH values (pHs 5, 7, and 9).

The important metabolites Terbufos sulfoxide and Terbufos sulfone are more mobile and persistent than parent Terbufos, and EFED is assuming they are equally toxic. The sulfoxide and sulfone have non-linear half-lives of 116 and 96 days, respectively. These metabolites are also mobile in all tested soils with Freundlich K_{ads} values ranging from 0.40 - 2.93, and may reach ground water when Terbufos is used in a location where irrigation or rain water moves through the soil profile to groundwater. In addition, Terbufos and its metabolites may enter surface water as a result of run-off events.

Terbufos is unstable in irradiated water with a half-life of only 1 day. Photolysis does not become an important means of dissipation in the field, however, because Terbufos is soil-incorporated. Also, in most bodies of water light penetration is not expected to be sufficient for photolysis to be considered a significant route of dissipation.

Volatilization may be a major dissipation route for the portion of parent Terbufos that remains on the surface of soil after incorporation. The relatively high vapor pressure (3.16×10^{-4} mm Hg) and observed Henry's Law Constant (6.58×10^{-3}) suggest that some of the parent compound will dissipate by diffusion into the atmosphere, but the amount that may volatilize will vary depending on the use site conditions and the mode of application.

b. Environmental Fate and Transport

I. Degradation

Hydrolysis of Parent Terbufos (161-1)--Terbufos degraded with half-lives of 12.3, 12.8, and 13.8 days in pH 5, 7, and 9 buffer solutions, respectively. The primary degradation product was formaldehyde, which accounted for 50-69% of the applied dose at 4 weeks (end of study). Terbufos sulfoxide and Terbufos sulfone, terbufoxon sulfoxide and sulfone (CL 94,365; phosphorodithioic acid, S-(t-butylsulfonyl) methyl,0,0-diethyl ester), CL 94,293 [(t-Butylthio) methanethiol], and three unknowns were minor metabolites (<3% of applied). (MRID #00087694)

Hydrolysis of Parent Terbufos and Terbufos Sulfoxide and Sulfone (161-1)The study was conducted using different temperatures for parent compound (10, 20, and 30 ^{o}C) than those used for Terbufos sulfoxide and sulfone. In addition, the registrant conducted the pH 5 and 7 studies for Terbufos sulfoxide and sulfone at 40, 50, and 60 ^{o}C and pH 9 metabolite studies at 20, 30, and 40 ^{o}C. This study design generally indicates that the compounds degrade faster at higher temperatures, regardless of pH. (MRID 44862501)

EFED did not use this study for risk assessment since the registrant provided the aerobic aquatic pond water study (MRID 44862502, 162-4) described below. The aerobic aquatic pond water study provided useful inputs for the EXAMS model.

Bowman and Sans (Open literature, 1982) reported that Terbufos degraded in aqueous solutions (pH 6 and 8.8) in darkness with half-lives of 3.2-3.5 days. The metabolite Terbufos sulfoxide degraded with half-lives of 33-41 days in pH 8.8 water, but degraded only slightly in distilled water (pH 6) with a half-life of 347 days. The sulfone metabolite was also pH-sensitive, with similar half-lives (277 days in pH 6 water and 18-32 days in pH 8.8 water).

Photolysis in water (161-2)--Terbufos degraded with a half-life of 1.2 days (28 hours) in pH 7 buffer solutions. Formaldehyde was 72% and 62% of the applied dose after 6 days of continuous irradiation. Terbufos sulfoxide and Terbufos sulfone were minor (<10% of the applied) metabolites. (MRID #00161567)

Aerobic soil metabolism (162-1)--Terbufos degraded in a silt loam soil with a half life of 27 days calculated using linear regression (log concentration against time), and with a half life of 6 days calculated by fitting the first-order degradation model using nonlinear regression, with untransformed concentration measurements. The 27-day half-life was originally calculated in previous documents, but EFED recalculated this half-life using non-linear regression because formation and decline analysis was used for modeling purposes. The major metabolites were Terbufos sulfoxide, Terbufos sulfone, and CO_2. Half-lives for these metabolites were 116 and 96 days, respectively, calculated using nonlinear regression. The maximum concentrations of these metabolites were 52, 20, and 46%, respectively. (MRID #00156853)

Felsot et al. (1982) reported that temperature is an important factor in Terbufos degradation in aerobic soil. The reported DT_{50} values were 100, 22, and 16 days in Flanagan silt loam at 6, 25, and 35 ^{o}C, respectively. The reported DT_{50} values were 38, 9, and 6 days in Gilford-Hoopeston-Ade sandy loam sandy loam at 6, 25, and 35 ^{o}C, respectively. Terbufos persistence in Flanagan silt loam at 25 ^{o}C was apparently unrelated to soil moisture contents of 12, 24, and 40% because the degradation rates were very similar throughout the study (Felsot, et al., 1982).

Anaerobic soil metabolism (162-2)--Terbufos degraded with a linear anaerobic half-life of 67 days (21 days for non-linear analysis) in nonsterile flooded silt loam soil that was incubated under a nitrogen atmosphere for 60 days following 9 days of aerobic incubation. The half-lives for terbufos sulfoxide were 14 days (linear) and 7 days (non-linear). Parent Terbufos was 26.1% of the applied dose at 60 days of anaerobic conditions. The major metabolite was CO_2, which reached a maximum of 35% of the applied dose. The metabolites Terbufos sulfoxide and sulfone, and terbufoxon sulfone and sulfoxide were <2.6% of the applied dose throughout the study. The volatile residues increased with time to 38.6% at 60 days. The soil-extractable and water residues decreased with increasing anaerobic time, and the soil residues were approximately 3-4X those of the flood water. Because the conditions were aerobic initially, the calculated anaerobic half-life is probably an underestimation of the true anaerobic soil half-life. (MRID #41749801)

Aerobic Aquatic Metabolism (162-4)–This study is acceptable and provides useful information on the degradation of parent Terbufos. However, the registrant submitted the aerobic aquatic pond water study below that incorporated the metabolites sulfoxide and sulfone. Therefore, EFED did not use this study as a model input into EXAMS.

Sand Sediment

The half-life in the sand sediment:water system was 27 days. Terbufos residues in water decreased from 44 % of applied at 6 hours to non-detectable levels by 50 days. Terbufos residues in sediment decreased from a maximum of 59 % at day zero to <10 % by 14 days. Terbufos in the glycol traps (volatile Terbufos) and NaOH traps (CO_2) increased as the levels in sediment and water decreased, reaching 21-45 % and 32 %, respectively.

Loam Sediment

The half-life in the sand sediment:water system was 41 days. Terbufos residues in water decreased from 16-17 % of applied at 6 hours to non-detectable levels by 7-14 days. Terbufos residues in sediment decreased from a maximum of 59 % at 6 hours to 11 % by 100 days (end of study). Terbufos in the glycol traps (volatile Terbufos) and NaOH traps (CO_2) increased as the levels in sediment and water decreased, reaching 9-31 % and 52 %, respectively. (MRID #44672004)

Aerobic Aquatic Metabolism in Pond Water Only (162-4)–The pond water study is acceptable and provides useful information for modeling purposes. EFED used these data in EXAMS to determine the persistence of parent Terbufos, Terbufos sulfoxide, and Terbufos sulfone, the formation rate of Terbufos sulfoxide from applied parent, and the formation rate of Terbufos sulfone from applied sulfoxide. Terbufos degraded with an aerobic half-life of 1.5 days (upper 90^{th} confidence bound on mean of two replicates) using non-linear analysis in nonsterile pond water that was incubated for 30 days. Parent Terbufos reached non-detectable levels by 7 days. Applied Terbufos sulfoxide degraded with a half-life of 68 days (upper 90^{th} confidence bound on mean of two replicates) and declined to 50-62 % by 30 days (end of study). Applied Terbufos sulfone degraded with a calculated half-life of 32 days (upper 90^{th} confidence bound on mean of two replicates) and declined to 39-43 % of applied by 30 days. The major metabolite was formaldehyde, indicating that hydrolyis proceeded faster than metabolism that would produce sulfoxide and sulfone metabolites. (MRID #44862502)

Laboratory volatility (163-2)--Although the vapor pressure value would trigger the need for a laboratory volatility study, this study is not required at the present time because Terbufos is soil incorporated and because the Agency is requiring additional data on the dissipation of Terbufos in the field.

ii. Mobility

Mobility/Adsorption/Desorption (163-1)--Based on the above batch equilibrium study, parent Terbufos is moderately mobile in an Arkansas loamy sand (K_{ads} = 5.42), and essentially immobile in an Indiana silt loam, New Jersey sandy loam, and Wisconsin loam soils (K_{ads} = 11.4-14.6). Freundlich K_{des} values ranged from 3.7-8.2 for the above soils, which was probably due to degradation. The Freundlich K_{ads} values for Terbufos sulfoxide and Terbufos sulfone were 2.8-2.9 for the Indiana silt loam (1.8% organic carbon), but only ranged from 0.4-0.86 for the other soils (0.29-1.39% OC). Adsorption of parent Terbufos appears to be highly related to soil organic carbon content and somewhat related to soil texture. (MRID #41373604)

iii. Accumulation

Accumulation in Laboratory Fish (165-4)--Terbufos bioaccumulated in bluegill sunfish with maximum bioaccumulation factors of 320, 940, and 680X in edible tissues (body, muscle, skin), non-edible tissue (fins, head, internal organs), and whole fish, respectively, during 28 days of exposure to ^{14}C-Terbufos residues at 0.05 ug/L in a flow through system. Maximum levels of ^{14}C-residues were 16 ug/L in edible tissues, 58 ug/L in nonedible tissues, and 34 ug/L in whole fish. After 14 days of depuration, ^{14}C-residues in edible and nonedible tissues and whole fish were 2.5 ug/L, 3.5 ug/L, and 2.3 ug/L, respectively. The main residues in water and in fish were parent Terbufos, terbufoxone (CL 94,221), and a methane-related derivative (CL 202,474; t-butylsulfinyl(methylsulfinyl)-methane). (MRID 41373603, 41373605)

The reported BCFs for Terbufos (320X to 940X) indicate that Terbufos has only a moderate potential for bioaccumulation.

iv. Field Dissipation

Terrestrial field dissipation (164-1). The terrestrial field data reviewed to date were considered upgradeable pending submission of storage stability data. Upgradeable data indicated that Terbufos dissipated in the field with half-lives of 24 days in loam soil (2.1 % OM) in California and 14-40 days in loamy and sandy loam soils in Illinois and Colorado. Approximately 85% of the applied Terbufos degraded between 14 and 30 days when moisture was applied to the field in California. These half-lives are comparable to the aerobic soil metabolism half-life of 27 days. Only trace levels of the metabolite Terbufos sulfoxide was detected below 6 inches of depth. The lack of vertical mobility in the registrant's studies may be explained by the higher organic matter content of the loam soil in California (2.1 %) and the lack of precipitation early in the studies.

Felsot et al. (1987) reported half-lives of 11-16 days for parent Terbufos and total toxic residue half-lives of 25-28 days in silt loam and silty clay loam soils in the field when Terbufos (Counter 15G™) was applied at 1 lb. ai/A to moldboard plowed, chisel plowed, and no tillage plots. Mobility was not evaluated in this literature study.

3. Water Resources

This section provides *estimated concentrations of Terbufos and Terbufos metabolites* in surface water and ground water for use in assessing exposure to aquatic organisms and to humans by drinking water. Also provided is a *description of environmental fate properties* of Terbufos and Terbufos metabolites as they relate to the potential for effects on the quality of surface and ground water. The major concerns raised by the use of Terbufos are potential leaching of Terbufos sulfoxide and Terbufos sulfone to ground water and potential runoff of parent Terbufos and these metabolites to surface water.

a. Ground Water

Because of their chemical characteristics, the two major metabolites of Terbufos, Terbufos sulfone and Terbufos sulfoxide, have more potential to leach to ground water in vulnerable areas than the parent. Terbufos parent is not as likely to leach but, as shown by the monitoring data below, it too can move to ground water as a result of normal field use. Because an MCL has not been established for Terbufos and its metabolites, no monitoring is required under the Safe Drinking Water Act.

Occurrence of Terbufos in ground water. This section presents summaries of individual sources of information focusing on Terbufos and Terbufos metabolites in ground water (summarized in Table 1). The information is from several sources including registrant-conducted studies, U.S. Geological Survey (USGS) monitoring, state monitoring information, and EPA's Pesticides in Ground Water Database. Results of ground water monitoring studies are displayed in Table 1 below.

These data represent 4,563 samples from 13 states, including 20 detections of parent Terbufos with an additional 7 apparent detections in Iowa that are questionable or unconfirmed. Thirteen wells were also sampled in Iowa for Terbufos sulfone, but no residues were detected.

Ground water monitoring studies. Overall, monitoring efforts for Terbufos have been limited. Monitoring has been conducted in some of the states within the Terbufos major use area. Terbufos parent has been detected in one well in Missouri at a concentration of 0.06 ppb, from suspected normal field use. One well in Nebraska contained parent Terbufos at a concentration of 0.02 ppb. In South Dakota, Terbufos was one of the most commonly detected pesticides in one study and was found at concentrations ranging from 0.011 to 0.050 ppb. Terbufos was detected in Indiana at 12.0 ppb in one domestic well and at 20 ppb in a spring. In Iowa, Terbufos parent was reported in ground water from public water supply wells. However, these detections in Iowa are inconclusive because there appeared to be problems with the analytical method.

In general, the available monitoring studies are not adequate to assess the potential for Terbufos to reach ground water because the Terbufos metabolites were not analyzed. The minimum detection limits for Terbufos were occasionally higher than the Terbufos Health Advisory (Illinois, Indiana, Mississippi), and there is no clear connection between Terbufos use areas and the wells sampled. Therefore, results from these studies are inconclusive because the Terbufos use areas did not necessarily coincide with monitoring sites. In addition, most studies were conducted on public water supply wells that draw large amounts of water from several depths within one or more aquifers. The use of water from different aquifers drawn from a single well may indicate that the water may not have originated during periods when Terbufos was in use. Therefore, a non-detection may not be meaningful.

State-by-State Summaries of Ground Water Monitoring Results.

Georgia. Barber, et al., (1984), Davis and Turlington (1985), and Davis and Turlington (1986) sampled ground water in Georgia for parent Terbufos (76 samples total). The limit of detection was 3 ug/L, which is above the Health Advisory of 0.9 ug/L. There were no detections; however, EFED has not confirmed whether or not there was use of Terbufos in Georgia during the period of sampling.

Illinois. Felsot (1984) sampled the inside faucets from 25 sand point wells. No Terbufos, Terbufos metabolites, or other pesticides were detected above 1 ppb. However, the results were inconclusive because of the sampling technique, the types of wells used, and the inability to characterize "spurious" peaks on the chromatogram.

Sinnott (1987) and Cobb and Sinnott (1988?) sampled public water supply wells for Terbufos parent. Parent Terbufos was not detected. Terbufos metabolites were analyzed for, but not detected.

Indiana. In 1986, the Indiana Department of Natural Resources and the Department of Environment Management sampled 24 private wells for Terbufos and other pesticides (IN DEM, 1988). Using a detection limit of 0.50 ppb for parent Terbufos, no residues were detected. No Terbufos metabolites were analyzed.

Ground-water monitoring data for pesticides from 1986 to 1990 in Indiana were compiled in a report by Risch (1994). A combination of public community wells, non-community water supply wells, monitoring wells, and rural domestic wells were sampled during several studies for a total of 206 wells. Many of the sampled areas were considered vulnerable. Several detection limits ranging from 0.03 to 1.5 ppb were achievable for parent Terbufos. Parent Terbufos was detected in one domestic well and one spring at concentrations of 12.0 and 20.0 ppb, respectively. Both of these detections exceed the Health Advisory (HA) of 0.9 ug/L. Resampling was conducted approximately six weeks later and no residues were found. No information about the origin of the Terbufos residues in ground water was provided. No Terbufos metabolites were analyzed for.

Statewide inferences about the occurrence of pesticides in ground water in Indiana cannot be based solely on this data compilation. The results were not due to a single statistical design, but instead were derived from a combination of many data sets. Among the studies, there was bias or variation in the selection of sample sites, in the timing and frequency of sample collection, and in the selection and minimum reporting limits of analytes.

<u>Iowa</u>. Samples have been collected from 787 wells in Iowa and analyzed for Terbufos residues in studies between 1984 and 1989. Iowa had seven of the 27 reported Terbufos detections in ground water nationwide, all of which came from five municipal well systems (public drinking water supply systems).

The registrant has disputed the detections of Terbufos in Iowa municipal wells, and EPA has concluding that the findings were either not-confirmed or were attributed to point sources [Susan Wayland of EPA to William A. Stellar of Cyanamid, 10 Jan. 89]. The registrant provided a copy of the report, in which the study authors themselves believe that the lab may have misidentified Terbufos in the 1985 Little Souix study (Kelly, Iowa Department of Natural Resources, 9/18/98 fax). It was suggested that the problem with the detections may be related to the EPA contract lab methodology. Upon consideration of the additional information, EFED cannot draw any conclusions based on the results of the Iowa study.

<u>Minnesota</u>. In 1986 and 1987, the Minnesota Department of Health (MDH) sampled public water supply wells across the state in areas susceptible to pesticide contamination (Klaseus et al., 1988). Samples were analyzed for parent Terbufos only; no metabolites were analyzed. No detections of parent Terbufos were found.

In another study, MDH and the Minnesota Pollution Control Agency sampled private drinking water supply wells in vulnerable areas (Klaseus and Hines, 1989). A subset of these wells and three public drinking water wells were resampled. Terbufos parent was analyzed; no residues were found. No metabolites were analyzed for.

<u>Missouri</u>. From 1986 to 1987, samples were taken from domestic, irrigation, and public water supply wells in the Mississippi River Valley alluvial aquifer (Mesko and Carlson, 1988). Only Terbufos parent was analyzed; Terbufos was detected in one well at a concentration of 0.06 ppb and was thought to be present as a result of normal use of Terbufos.

In another study from 1987 through 1990, the Missouri Department of Natural Resources sampled rural drinking water wells in the State (Sievers and Fulhage, 1991). Terbufos parent was not detected; metabolites were not analyzed.

Mississippi. In Mississippi, a statewide ground-water monitoring survey was designed to sample for pesticides in major crops such as cotton and soybeans. Both drinking water and irrigation wells are sampled (Landreth, 1996). Although Terbufos has not been used in the State, it is one of the chemicals in the suite of analytes that is reported. No residues have been detected using a detection limit of 2.4 ppb. It is not clear if Terbufos sulfoxide and sulfone were analyzed for in the studies. Because of the lack of use in the state, the lack of detections is not significant.

Montana. From 1984 to 1988, a combination of domestic drinking water, livestock, and irrigation wells were sampled for pesticide residues by the Montana Department of Agriculture (DeLuca et al, 1989). Thirteen wells were sampled for Terbufos parent; no residues were detected. No metabolites were analyzed for.

Nebraska. Pesticide data available before 1989 were collected and published by Exner and Spalding (1990). Data were collected by the Nebraska Department of Health, the Nebraska Department of Environmental Control, the Lincoln-Lancaster County Health Department, U.S. Geological Survey and others. Five types of wells are included in the assessment including domestic (greatest number), irrigation, public supply and municipal, stock, and monitoring. One well contained parent Terbufos at 0.02 ppb; no metabolites were analyzed.

Pennsylvania. Ground water from 22 wells and two springs in the Mahantango Watershed was analyzed for several pesticides including Terbufos that were heavily used in the watershed (Pionke et al., 1988; Pionke and Glofelty, 1989). All wells were located in unconfined aquifers. No Terbufos parent was detected; no metabolites were analyzed.

Rhode Island. Twenty-four private drinking water wells were sampled for Terbufos in corn-growing areas. Terbufos parent was not detected; metabolites were not analyzed (RI DEM, 1990).

South Dakota. Forty-one monitoring wells in three aquifers were sampled by the Department of Environment and Natural Resources from 1988 to 1992 (SD DENR, 1993). Terbufos was one of the most commonly detected pesticides and was found in 16 wells in all three aquifers. Concentrations in the Parker-Centerville aquifer ranged from 0.011 to 0.050 ppb in 1992. No metabolites were analyzed for.

Table 1. Ground Water Monitoring Data for Terbufos

Study	Well Type	Number of Wells Sampled	Minimum Detection Limit (ppb)	Number of Wells with Detections	Concentration Range (ppb)
Georgia (1984-1986)	community and non-community water systems	76	3.0	0	0
Little Sioux River, IA (1984-86)	public water supply, monitoring	103	0.1 (parent) (sulfone; analyzed in 8 wells)	7	0.3-20.0 (parent)*
Iowa monitoring (1984-89)	public water supply (drinking water)	684	0.1 (parent)	0	0
Illinois monitoring (1985-88)	sand point; public water supply	466	1.0, 0.05 (parent) 0.05 (metabolites)	0	0
Indiana (1986-90)	drinking water; community water supply	206	0.03-1.5 (parent)	2	12.0-20.0
Minnesota (1986-90)	public water supply, private drinking water	649	0.2 (parent)	0	0
Missouri (1986-90)	public water supply, private drinking water, irrigation	325	0.05, 0.1, 0.3 (parent)	1	0.06
Mississippi (1989-96)	drinking water, irrigation	459	2.4 (parent)	0	0
aMontana (1984-88)	livestock, domestic drinking water, irrigation	13	1.0 (parent)	0	0
Nebraska (<1989)	domestic, irrigation, public supply and municipal, stock, monitoring	1435	0.25 (parent)	1	0.02
Pennsylvania (1985-87)	monitoring?	24	0.003-0.01 (parent)	0	0
Rhode Island (1986)	private drinking water	24	?	0	0
South Dakota (1988-92)	monitoring	99	0.010 (parent)	16	0.011-0.050

*The detections of Terbufos in the Little Sioux River public water supply study are in question and may be due to laboratory problems.

Estimated concentrations in ground Water (SCI-GROW). Table 2 presents estimates of Terbufos and Terbufos metabolites in ground water based on the SCI-GROW model (Barrett, 1997). The SCI-GROW model (Screening Concentrations in Ground Water) is a model for estimating "upper bound" concentrations of pesticides in ground water. SCI-GROW provides a screening concentration; an estimate of likely ground water concentrations if the pesticide is used at the maximum allowed label rate in areas with ground water vulnerable to contamination. In most cases, a majority of the pesticide use area will have ground water that is less vulnerable to contamination than the areas used to derive the SCI-GROW estimate.

The SCI-GROW model is based on scaled ground water concentrations from ground water monitoring studies, environmental fate properties (aerobic soil half-lives and organic carbon partitioning coefficients-Koc's) and application rates. The SCI-GROW model does not make use of information on application procedures.

The EECs and some of the discussion from a 1/5/99 memorandum on drinking water have been included in this section. EFED has estimated total toxic concentrations of Terbufos since adequate environmental fate data on degradates are available as inputs for the SCI-GROW model. EFED has also provided EECs for parent Terbufos for comparison purposes. Table 2 below presents the maximum acute and chronic **ground water** EECs for the total toxic residues of Terbufos using the SCI-GROW model. These EECs are appropriate for the dietary exposure assessment. The residues of parent Terbufos, Terbufos sulfoxide, and Terbufos sulfone in the aerobic soil metabolism study (MRID 00156853) were added for each sampling interval, and the half-life was calculated by linear regression of the log of the summed concentration against time.

Table 2. Acute and Chronic Concentrations of Total Toxic Residues of Terbufos in Ground Water using the Tier 1 Model SCI-GROW.[1]

Crop and Application Rate	Acute and Chronic (ug/L)
Corn (Parent only, 1.3 lbs ai/A maximum rate)[2]	0.007
Corn (Total toxic residue, 1.3 lb ai/A maximum rate)[2]	4.8
Grain Sorghum (Parent only, 2 lbs ai/a maximum rate)[3]	0.01
Grain Sorghum (Total toxic residue, 2 lbs ai/a maximum rate)[3]	7.4
Sugar Beets (Parent only, 2 lbs ai/A maximum rate)[4]	0.01
Sugar Beets (Total toxic residue, 2 lbs ai/A maximum rate)[4]	7.4

[1] This assumes the total toxic residue (parent + sulfoxide + sulfone) half-life from the aerobic soil metabolism study (MRID 00156853) of 129 days and the lowest K_{oc} of Terbufos sulfoxide and sulfone of 58 ml/g for an estimate of mobility. This K_{oc} value was chosen because the adsorption of these metabolites was highly related to soil pH (r^2=0.96-0.98). The different rates in this table are based on the label and the 9/16/97 fax from John Wrubel of American Cyanamid. For parent Terbufos only, EFED assumed a Koc of 633 and a half-life of 5.6 days from the same studies

[2] For corn. The 9/16/97 fax from John Wrubel of American Cyanamid stated that the typical application rate for corn was 1.1 lbs ai/A for each application procedure.

[3] For grain sorghum and sugar beets. The 9/16/97 fax from John Wrubel of American Cyanamid stated that the maximum labeled application rate for in-furrow and banded uses of Terbufos is 2.0 lbs ai/A, and that >95 % of Terbufos use on these crops is banded or used in-furrow. These numbers take into account the recent label amendment for a maximum rate of knifed-in Terbufos to 2 lbs ai/A from 3.9 lbs ai/A.

[4] For grain sorghum and sugar beets. This is a high exposure case because most (>95 %) of Terbufos use is banded or in-furrow at a maximum labeled rate of 2.0 lbs ai/A. The typical use rate for grain sorghum is 0.75 lb ai/A and the typical use rate for sugar beets is 1.1 lbs ai/A. (9/16/97 fax). These numbers take into account the recent label amendment for a maximum rate of knifed-in Terbufos to 2 lbs ai/A from 3.9 lbs ai/A.

b. Surface Water

Fate and Transport Properties. Hydrolysis and microbial degradation appear to be the most important means of Terbufos dissipation in the environment. Terbufos is very unstable to photolysis in water, but photolysis may not be important because light penetration in surface water is often limited. In the terrestrial environment Terbufos is incorporated or knifed in to a depth where sunlight does not contribute to its degradation.

Information from environmental fate studies indicates that parent Terbufos will be moderately persistent in surface waters. The reported half-lives for hydrolysis (pH values of 5, 7, and 9), aerobic soil metabolism and anaerobic aquatic metabolism were 12.3-13.7, 5.6, and 67 days, respectively. The reported half-life for photodegradation in water was 1 day. However, photodegradation in water is not expected to significantly decrease surface water concentrations because of potential suspended sediments and presence of the chemical below the photic zone. The reported vapor pressure (3.16×10^{-4} mm Hg), Henry's Law Constant of 6.58×10^{-4} atm m^3 / mol, and the solubility in water (5 ppm) indicate that parent Terbufos has moderate volatility potential in surface water. This would potentially lower Terbufos residues in surface water.

In the modeling, EFED did not calculate the amount of Terbufos residues in sediment. This is because the metabolites are very mobile and would likely be associated with the water column.

In soil, parent Terbufos transforms into the oxidative metabolites Terbufos sulfoxide and Terbufos sulfone. These metabolites are more mobile (Freundlich K_{ads} values of 0.4-2.8 and 0.55-2.93, respectively) and more persistent ($T_{1/2}$'s of 116 and 96 days, respectively) than parent Terbufos ($T_{1/2}$ of 5.6 days). Consequently, they should be available for runoff for a longer period of time than parent Terbufos, and should have higher fractions dissolved in runoff water and in the water column than parent Terbufos. The available data on soil and in water suggest that the metabolites may also be more persistent in surface water than Terbufos.

Terbufos Occurrence in Surface Water.

According to pre-1988 listings in STORET, Terbufos was detected in 134 of 2,016 surface water samples at an 85th percentile of detections of 0.1 ug/L and a maximum concentration of 2.25 ug/L. Baker (1988) sampled 8 tributaries of Lake Erie from April 15-August 15 of 1983 through 1985. He reported April 15-August 15 time weighted means for Terbufos ranging from < 0.001 to 0.096 ug/L and averaging 0.008 ug/L. Maximum concentrations ranged from below a detection limit of 0.01 ug/L to 2.25 ug/L and averaged 0.21 ug/L. The State of Illinois (Moyer and Cross 1990) sampled 30 surface water sites for pesticides at various times from October 1985 through October 1988. Although substantial use in Illinois was a criterion for pesticides being included in the analyses, total Terbufos was not detected in any of the samples at or above the detection limit of 0.05 ug/L. The STORET database also contained USGS NAWQA data from 8 widely-spread locations within the Mississippi Basin at frequent intervals from April 1991 to April 1992. Terbufos was detected at concentrations between 0.01 and 0.1 ug/L in one of the 47 samples collected from the Platte River and in one of the 45 samples collected from the Illinois River. Terbufos was not detected above a detection limit of 0.02 ug/L in any of the samples collected from the other 6 locations. No data were available from these studies on the concentrations of the sulfoxide or sulfone metabolites in water bodies sampled.

The USGS (Kimbrough and Litke 1995) has sampled the South Platte River in Colorado, the Platte River in Central Nebraska, the White River in Indiana, the Rio Grande River in Texas, New Mexico, and Colorado, the San Joaquin River in California, and the Albemarle-Pamlico River in Virginia and North Carolina for parent Terbufos. With a detection limit of 0.013 ug/L, detected residues of parent Terbufos ranged from 0.013-0.56 ug/L. These watersheds are locations where corn, grain sorghum, and sugar beets are grown. The data EFED has received consist of 214 samples.

The monitoring information in the previous paragraph is broken down below. There are 17 detections of parent Terbufos in 5,198 samples in the USGS NAWQA database for surface water. One estimated detection (pending QA/QC) of 0.01 ppb was observed in the Albermarle-Pamlico River. There also 16 confirmed detections ranging from 0.013-0.56 ppb. (See Table 3 below for details). In the South Platte River, there were 6 detections of parent Terbufos ranging from 0.03 to 0.56 ug/L. The higher detections were found in May and early June, when application would be expected, while the lower detections were in July. In the Central Nebraska River, there were 3 detections ranging from 0.023-0.27 ug/L. The higher detections were observed in May, when application would be expected, while the 0.023 detection was found in August. In the San Joaquin River in California, there were 2 detections of 0.1 and 0.024 ug/L. In the Lower Susquehanna River Basin in Pennsylvania and Maryland (LSUS), the White River in Indiana, the Rio Grande River in Colorado, New Mexico, and Texas, and Georgia-Florida Rivers, there were 6 combined detections ranging from 0.013-0.03 ug/L.

Limitations of NAWQA Data

The NAWQA program was designed to describe the status and trends of a representative portion of the nation's water quality and to provide a sound scientific understanding of the primary natural and human factors affecting the water quality (Hirsch et al., 1988). The program is not targeted to reflect concentrations of pesticide resulting from use within the sampled watersheds.

Table 3. NAWQA Surface Water Data for Terbufos				
Study Location	Number of Samples	Number of Detections	Range of Concentrations (ug/L)	% of Samples with Detections by Location
Appalachicola-Chattahoochie-Flint River Basin	432	0	--	0
Albermarle-Pamlico	256	1	0.01 (estimated)	0.39
Central Columbia Plateau	231	0	--	0
Central Nebraska	157	3	0.023-0.27	1.9
Connecticut	141	0	--	0
Georgia-Florida	384	1	0.018	0.26
Hudson	264	0	--	0
Lower Susquehanna River Basin	408	1	0.03	0.25
Nevada	134	0	--	0
Ozark	157	0	--	0
Potomac	288	0	--	0
Red River of the North	216	0	--	0
Rio Grande	178	1	0.016	0.56
San Joaquin	437	2	0.024-0.1	0.46
South Platte	157	6	0.03-0.56	3.8
Trinity	331	0	--	0
Upper Snake River Basin	150	0	--	0
White	544	2	0.013-0.16	0.37
Williamette	184	0	--	0
Western Lake Michigan Drainage	149	0	--	0
Total	5,198	17		0.33 % (overall)

EPA has received reports of 85 fish kill incidents associated with Terbufos use. Most of these have been in farm ponds. However, large fish kill incidents have occurred in lakes and other bodies of water 10-28 days after Terbufos application. Up to 50,000-90,000 fish have died in a single incident. Therefore, it is apparent that residues of Terbufos or Terbufos metabolites can reach levels toxic to fish over an extended period of time. Humans could also be exposed to similar levels in untreated water.

Tier II Estimated Surface Water Concentrations. Tier II estimated environmental concentrations (EECs) have been calculated for parent Terbufos applied to field corn in Ohio, grain sorghum in Kansas, and sugar beets in Minnesota, using PRZM 3.12 and EXAMS 2.975. (Previous modeling used PRZM 2.3 and EXAMS 2.94 and for corn, and an Iowa scenario was modeled.) EFED is also using a recently-approved label that reduces the maximum rate for knifed-in applications of terbufos for sugar beets and grain sorghum (3.9 lbs ai/a to 2 lbs ai/a). EFED has also calculated EECs for surface water for total toxic residues of those Terbufos residues that are observed in environmental fate studies (parent, Terbufos sulfoxide and sulfone). Tier II EECs are used to assess drinking water exposure and exposure to aquatic organisms for surface water. A Tier II EEC for a particular crop or use is based on a single site that represents a high exposure scenario for the crop or use. Weather and agricultural practices are simulated at the site for 36 years to estimate the probability of exceeding a given concentration (maximum concentration or average concentration) in a single year. Maximum EECs are calculated so that there is a 10% probability that the maximum concentration in a given year will exceed the EEC at the site; 4-day, 21-day, 60-day, and 90-day average EECs are calculated so that there is a 10% probability that the maximum average concentration for a given duration (4-day, 21-day, etc.) will equal or exceed the EEC at the site. This can also be expressed as an expectation that water concentrations will exceed EECs once every 10 years.

This revised RED Chapter contains updated EECs from modeling for both surface and ground water. This RED Chapter supersedes the memoranda dated 9/30/97 and 1/5/99 since it contains updated water concentrations. Since the previous memoranda, EFED has conducted additional modeling to estimate levels of parent terbufos and the oxidative metabolites terbufos sulfoxide and sulfone in surface water. EECs for these metabolites were not included in the 9/30/97 memorandum for either surface or ground water. This updated RED Chapter also contains the estimated environmental concentrations (EECs) for terbufos and the above oxidative metabolites in ground water from the 1/5/99 memorandum.

Since the previous water memoranda, EFED has received data on the abiotic hydrolysis of parent terbufos and the oxidative metabolites terbufos sulfoxide and sulfone. We have also received aerobic aquatic data for the above compounds in aerobic natural pond water. These data were submitted in response to the 11/24/98 memorandum which concluded that using the PRZM-EXAMS model to estimate surface water concentrations for these metabolites would not provide meaningful information at this time due to lack of data for either hydrolysis or aquatic metabolism.

The aerobic aquatic metabolism study (MRID 44672004) was screened and found to contain useful information for parent terbufos only. Therefore, EFED did not use the results from this study as a model input.

EFED did not use the abiotic hydrolysis data for surface water because the aerobic aquatic metabolism data are more relevant. For ground water, the hydrolysis data provide useful information on the persistence and degradation products if terbufos residues were to reach ground water.

Tier II upper tenth percentile EECs for parent Terbufos and the sulfoxide and sulfone metabolites are displayed in Table 4. Tables 5, 6, and 7 below present the Environmental Fate parameters used as inputs in the model for these compounds, respectively.

For the in-furrow and knifed-in uses, the model actually underpredicted the EECs that would likely be observed. Extremely low levels of parent terbufos and metabolites were predicted for all simulated in-furrow or knifed-in applications. PRZM does not move pesticides upward from a fixed depth even though this can occur in the field in finer-textured soils through capillary action. Some fish-kill incidents have been associated with in-furrow applications of terbufos.

Table 4. Tier II upper tenth percentile EEC's for Parent Terbufos

Application	Maximum ($\mu g \cdot L^{-1}$)	4 Day ($\mu g \cdot L^{-1}$)	21 Day ($\mu g \cdot L^{-1}$)	60 Day ($\mu g \cdot L^{-1}$)	90 Day ($\mu g \cdot L^{-1}$)	Annual Mean* ($\mu g \cdot L^{-1}$)
Corn						
Parent only Corn at 1.3 lbs ai/A T-banded (85 % in top 2 cm)	2.2	1.2	0.3	0.1	0.07	0.02
Total toxic residue Corn at 1.3 lbs ai/A T-banded (85 % in top 2 cm)	5.4	5.0	4.6	4.3	3.9	1.9
Parent Only Corn In-furrow (all at 1.0 inch of depth)	No residues were predicted to leave the field. This is a limitation of the model (See limitations discussion below).					
Total toxic residue Corn In-furrow (all at 1.0 inch of depth)	No residues were predicted to leave the field. This is a limitation of the model (See limitations discussion below).					

Table 4. Tier II upper tenth percentile EEC's for Parent Terbufos

Application	Maximum ($\mu g \cdot L^{-1}$)	4 Day ($\mu g \cdot L^{-1}$)	21 Day ($\mu g \cdot L^{-1}$)	60 Day ($\mu g \cdot L^{-1}$)	90 Day ($\mu g \cdot L^{-1}$)	Annual Mean* ($\mu g \cdot L^{-1}$)
Grain Sorghum						
Parent Only Grain Sorghum T-banded (85 % in top 2 cm)	4.5	2.2	0.6	0.2	0.2	0.04
Total toxic residue Grain Sorghum T-banded (85 % in top 2 cm)	13.3	12.7	12.1	11.0	9.9	5.5
Parent Only Grain Sorghum In-furrow (all at 1 inch of depth)	No residues were predicted to leave the field. This is a limitation of the model (See limitations discussion below).					
Total toxic residue Grain Sorghum In-furrow (all at 1 inch of depth)	No residues were predicted to leave the field. This is a limitation of the model (See limitations discussion below).					

Table 4. Tier II upper tenth percentile EEC's for Parent Terbufos

Application	Maximum ($\mu g \cdot L^{-1}$)	4 Day ($\mu g \cdot L^{-1}$)	21 Day ($\mu g \cdot L^{-1}$)	60 Day ($\mu g \cdot L^{-1}$)	90 Day ($\mu g \cdot L^{-1}$)	Annual Mean* ($\mu g \cdot L^{-1}$)
Sugar Beets						
Parent Only Sugar Beets T-banded (85 % in top 2 cm)	1.6	0.8	0.2	0.06	0.04	0.009
Total toxic residue Sugar Beets T-banded (85 % in top 2 cm)	4.3	3.8	3.4	3.0	2.8	1.3
Parent Only Sugar Beets Knifed In (all at 2 inches of depth)	No residues were predicted to leave the field. This is a limitation of the model (See limitations discussion below).					
Total toxic residue Sugar Beets Knifed In (all at 2 inches of depth)	No residues were predicted to leave the field. This is a limitation of the model (See limitations discussion below).					

* Upper 90% confidence bound on the 36 year mean with variance calculated from annual means.

Table 5. Environmental Fate Parameters used in PRZM-EXAMS Modeling for Parent Terbufos, Terbufos sulfoxide, and Terbufos sulfone.

Parameter	Value	Source (MRID unless specified)	Uncertainty Factor[1]	Rate Constants (K-value)
Parent Terbufos				
Freundlich K_{oc}	633 ml/g	41373604	Not Applicable	Not Applicable
Aerobic Soil Metabolism $T_{1/2}$	5.6 days[2]	00156853	None	1.24×10^{-1} day^{-1}
Aerobic Aquatic Metabolism $T_{1/2}$ (KBACW)	1.50 days[2]	44862502	None	4.65×10^{-1} hour^{-1}
Anaerobic Aquatic Metabolism $T_{1/2}$ (KBACS)	11.7 days[2]	41749801	None	2.5×10^{-3} hour^{-1}
Terbufos sulfoxide				
Freundlich K_{oc}	58 ml/g/	41373604	Not Applicable	Not Applicable
Aerobic Soil Metabolism $T_{1/2}$	117 days[2]	00156853	None	5.9×10^{-3} day^{-1}
Aerobic Aquatic Metabolism $T_{1/2}$ (KBACW)	68 days[2]	44862502	None	4.22.x 10^{-4} hour^{-1}
Anaerobic Aquatic Metabolism $T_{1/2}$ (KBACS)	116 days[2]	00156853	2	1.24×10^{-4} hour^{-1}
Terbufos Sulfone				
Freundlich K_{oc}	58 ml/g	41373604	Not Applicable	Not Applicable
Aerobic Soil Metabolism $T_{1/2}$	96 days[2]	00156853	None	7.22×10^{-3} day^{-1}
Aerobic Aquatic Metabolism $T_{1/2}$ (KBACW)	32 days[2]	44862502	None	8.92×10^{-4} hour^{-1}
Anaerobic Aquatic Metabolism $T_{1/2}$ (KBACS)	96 days[2]	00156853	2	1.49×10^{-4} hour^{-1}

[1] For laboratory metabolism studies, EFED normally multiplies a single metabolism study $T_{1/2}$ by 3 to account for the uncertainty of having only one half-life. Since EFED conducted a formation and decline analysis, no uncertainty factors were included, and the value given in Column 2 has been used in PRZM-EXAMS modeling, after conversion to a rate constant (Column 5).

[2] $T_{1/2}$ values used for PRZM-EXAMS modeling were calculated by fitting the first-order dissipation model using nonlinear regression with untransformed concentration measurements. For the KBACS (pond sediment) rate value in EXAMS, EFED used the aerobic soil half-life of terbufos sulfoxide (116 days) and sulfone (96 days), multiplied by 2 for a change in media, and converted this daily rate to an hourly rate.

Comparison of Modeling and Monitoring Results for Terbufos.

Maximum concentrations of parent Terbufos from PRZM 3.12 modeling were 1.6 ug/L for sugar beets, 2.2 ug/L for corn, and 4.5 ug/L for grain sorghum. Maximum concentrations of total toxic residues of Terbufos from PRZM 3.12 modeling were 4.3 ug/L for sugar beets, 5.4 ug/L for corn, and 13.3 ug/L for grain sorghum. Instead of the monitoring or modeling concentrations that take into account only parent terbufos, EFED recommends using the t-banded PRZM-EXAMS EECs for total toxic residues for each crop for both acute and chronic dietary exposure assessment.

Parent Terbufos was not found above 2.25 ug/L in monitoring data from the Midwest. However, the monitoring data are limited and often not associated with periods or areas of Terbufos use, and the quality for some data is unknown. Since they represent parent terbufos only, the monitoring data are useful for only a lower bound of environmental concentrations for parent terbufos only. However, the monitoring data do show that the PRZM-EXAMS modeling provides realistic estimates of exposure through drinking water, based on the similarity of the data. Based on the persistence and mobility of the sulfoxide and sulfone metabolites, monitoring data may actually exceed the EECs produced from PRZM-EXAMS.

c. Drinking Water Assessment

The major drinking water concerns associated with Terbufos use are potential leaching to ground water (only for the metabolites, terbufos sulfoxide and terbufos sulfone) and runoff to surface water (for parent terbufos as well as terbufos sulfoxide and terbufos sulfone). It is EFED's understands that the tolerance expression established for mammalian toxicity includes parent Terbufos, the metabolites Terbufos sulfoxide and sulfone, Terbufos oxon, and oxon sulfoxide and sulfone. Parent EECs were provided as well as total toxic residues that include parent Terbufos, Terbufos sulfoxide, and sulfone. These were the only Terbufos compounds with the organophosphate functional group that were observed in environmental fate laboratory studies in significant quantities.

Ground water concentrations for drinking water exposure assessment. Table 2 (above) displays estimated concentrations for ground water for use in dietary risk assessment, for parent Terbufos and the metabolites Terbufos sulfoxide and Terbufos sulfone, based on the SCI-GROW model. EFED recommends using the EECs for total toxic residues for each combination of crop and application method. EFED has presented EECs for parent Terbufos for purposes of comparison.

Uncertainties in estimating ground water concentrations. The SCI-GROW model is based on small-scale ground water monitoring studies conducted for aquifers beneath highly vulnerable sandy soils with shallow ground water (10-30 ft in depth). Uncertainties in the SCI-GROW model are: 1) The model does not consider site specific factors regarding hydrology, soil properties, climatic conditions, and agronomic practices; 2) The model does not account for volatilization, and 3) Predicted ground water concentrations are linearly extrapolated from the application rates. This model is based on actual field data from “upper bound” ground water monitoring studies conducted on sandy soils and with heavy irrigation. Therefore the results should be considered to be an "upper bound" for Terbufos and its residues in ground water.

Surface water concentrations for drinking water exposure assessment. Table 4 above contains surface water concentrations of total residues (parent terbufos+terbufos sulfoxide+terbufos sulfone) for use in dietary risk assessment, based on modeling with PRZM-EXAMS. Terbufos sulfoxide and terbufos sulfone are the only Terbufos metabolites having the organophosphate functional group that have been observed in significant quantities in fate studies. EFED recommends using the EECs for total residues for each crop and application method combination. EFED has provided the EECs for parent Terbufos for purposes of comparison. The water monitoring data are very limited for parent Terbufos, and no monitoring information for the Terbufos metabolites is available to EFED for surface water.

Limitations of Tier II Surface Drinking Water Assessment. Obviously, a single 10 hectare field with a 1 hectare pond does not accurately reflect the dynamics in a watershed large enough to support a drinking water facility. A basin of this size would certainly not be planted completely to a single crop nor be completely treated with a pesticide. Additionally, treatment with the pesticide would likely occur over several days, rather than all on a single day. This would reduce the magnitude of the concentration peaks, but also make them broader, reducing the acute exposure but perhaps increasing the chronic exposure. The fact that the simulated pond has no outlet is also a limitation as water bodies in this size range would have at least some flow through (rivers) or turnover (reservoirs). However, PRZM cannot simulate the upward movement of residues due to capillary transport that may occur in finer-textured soils. Therefore, PRZM may underpredict EECs when simulating applications such as knifed-in and in-furrow applications. Supporting evidence for underprediction is provided by the fish kill incidents.

In spite of these limitations, a Tier II EEC can provide a reasonable upper bound on the concentration found in drinking water if not an accurate assessment of the real concentration. The EECs have been calculated so that in any given year, there is a 10% probability that the maximum average concentration of that duration in that year will equal or exceed the EEC at the site. Risk assessment using Tier II values can reasonably be used as refined screens to demonstrate that the risk is below the level of concern.